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Introduction to Gas Turbines and Applications

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Contents

- How Does it Work?
- Gas Turbine Components
- Gas Turbine Performance
- Gas Turbine Applications

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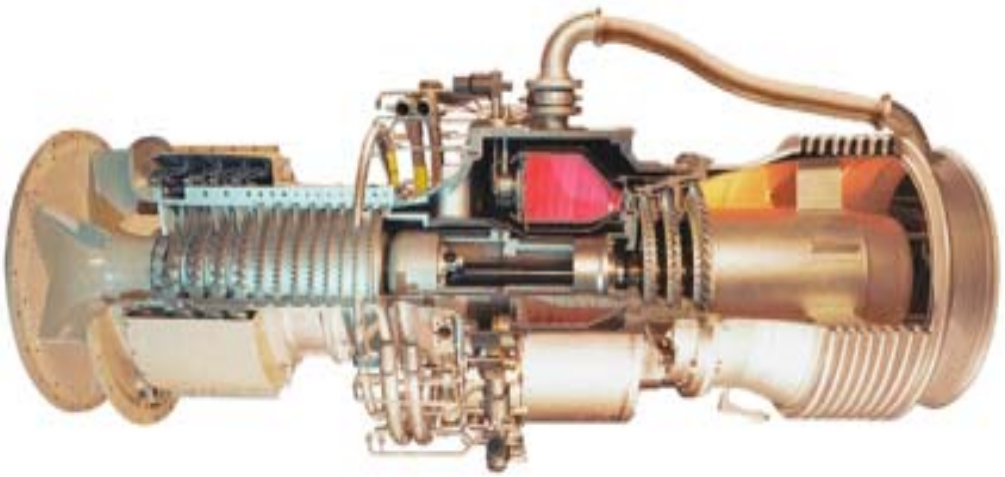
This is a Gas Turbine.



How does it work?

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Gas Turbine Movie

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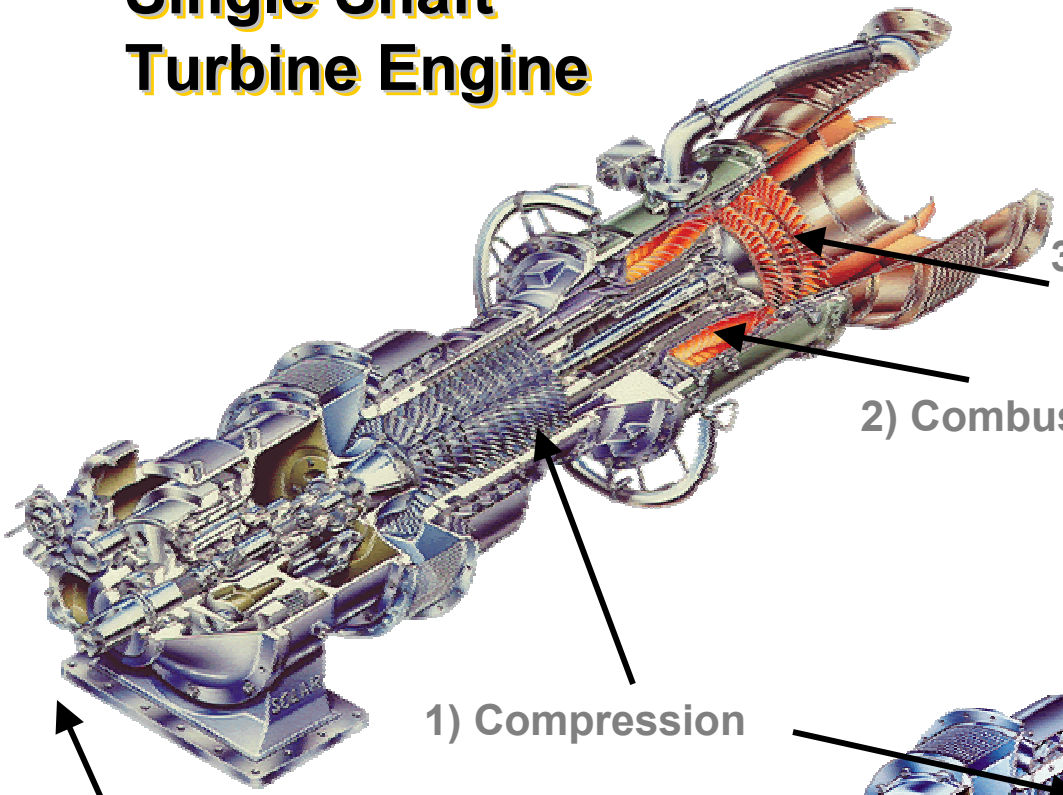
Single Shaft Turbine Engine



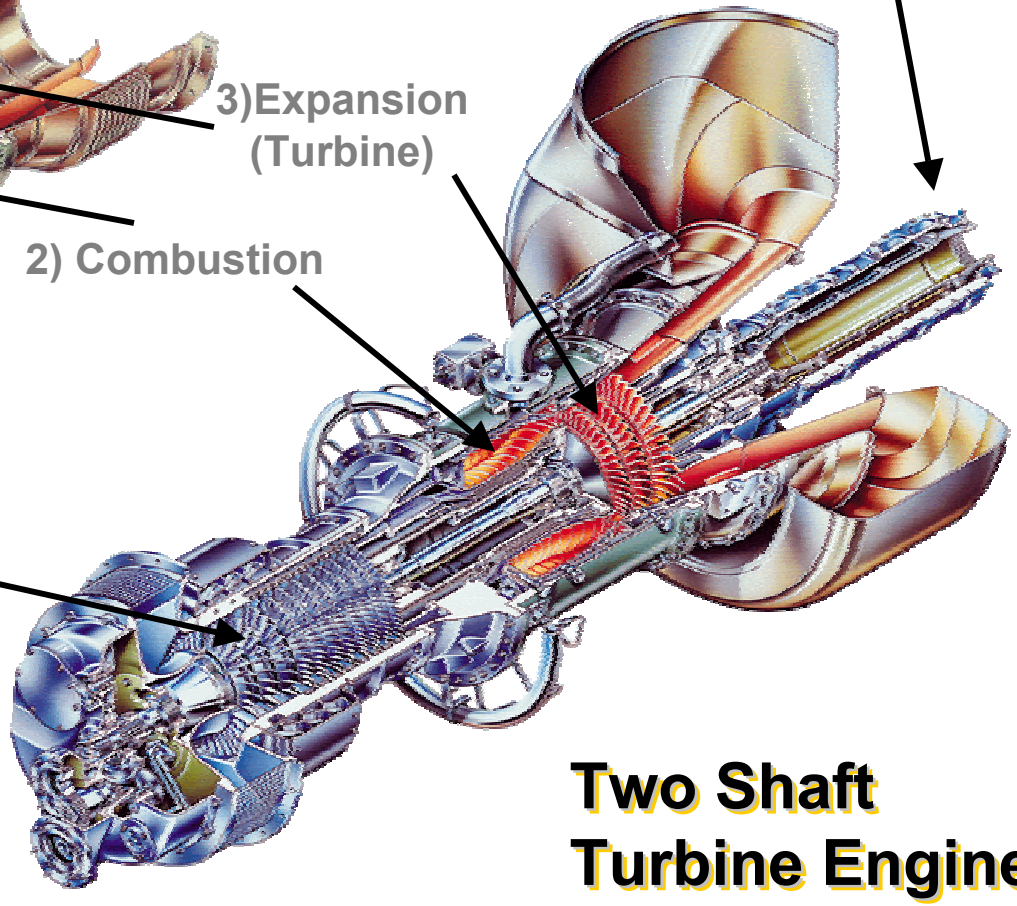
3)Expansion (Turbine)

2) Combustion

1) Compression

Output Shaft Power

Output Shaft Power



Two Shaft Turbine Engine

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The "Simple Cycle"

- Compressor Pumps Air into Combustion Chamber
- Fuel in Gaseous or Liquid Spray Form Injected into Combustion Chamber and Burned
- Continuously Expanding Combustion Products Directed Through Stationary Airfoils
  - react against the blades of a turbine wheel, causing the shaft to turn, driving the compressor
- Remaining High Energy Gas Can be Used
  - expansion across a nozzle (propulsion)
  - expansion across another turbine stage (shaft power)

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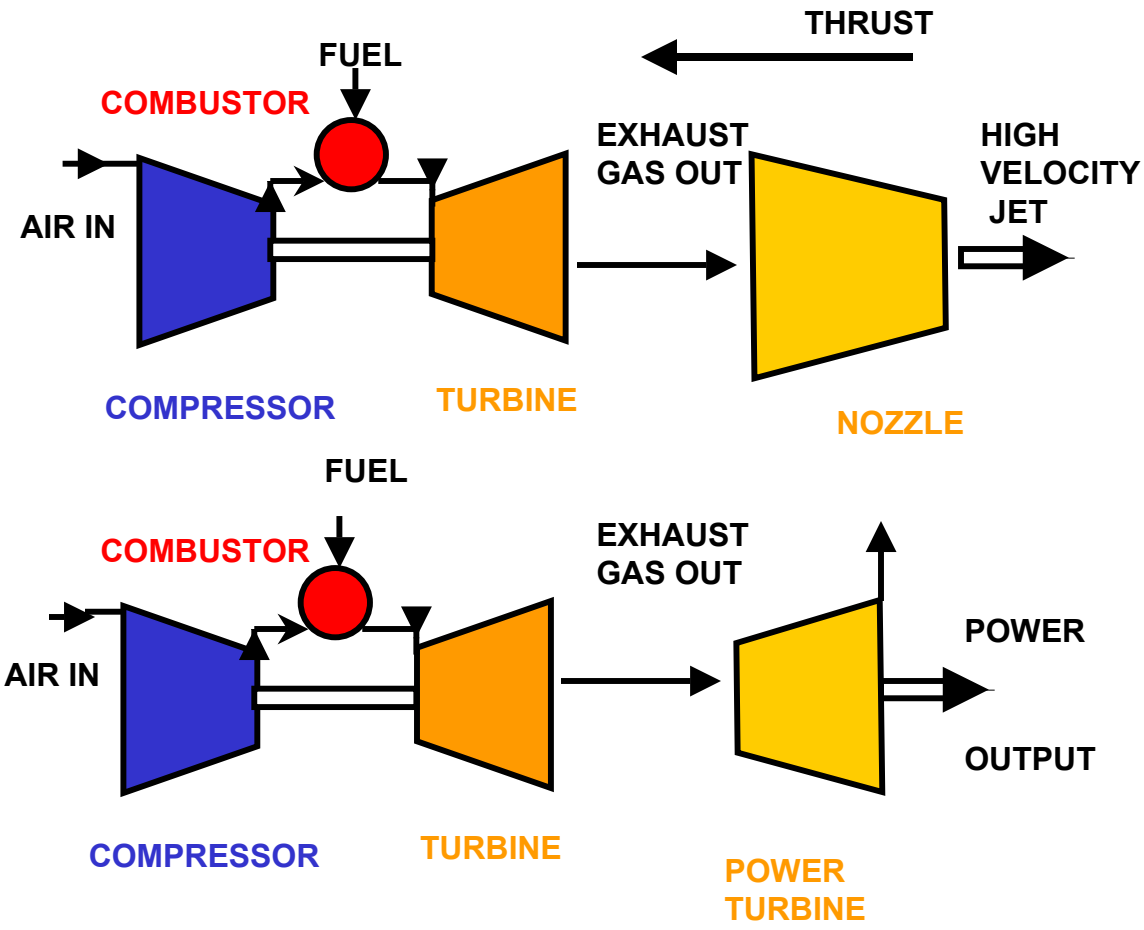
Simple Cycle Gas Turbines as Aircraft Engines and Land Based Prime Movers



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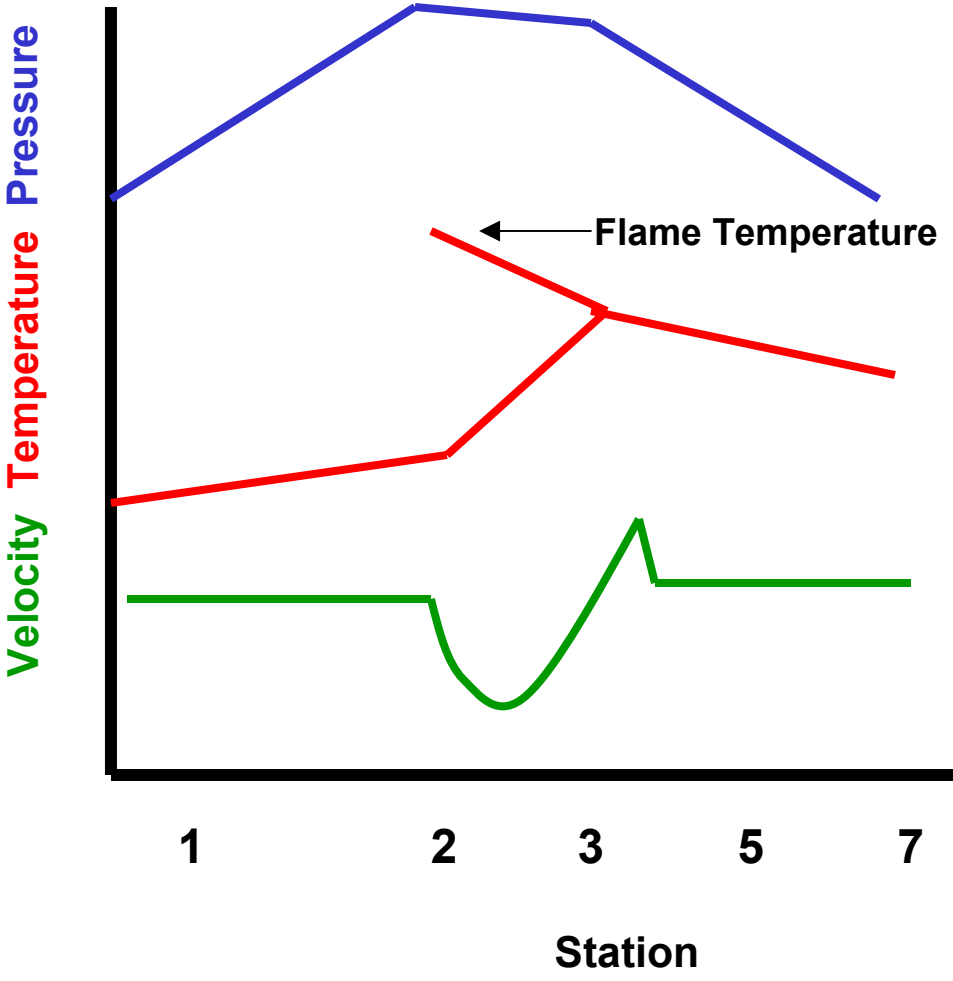
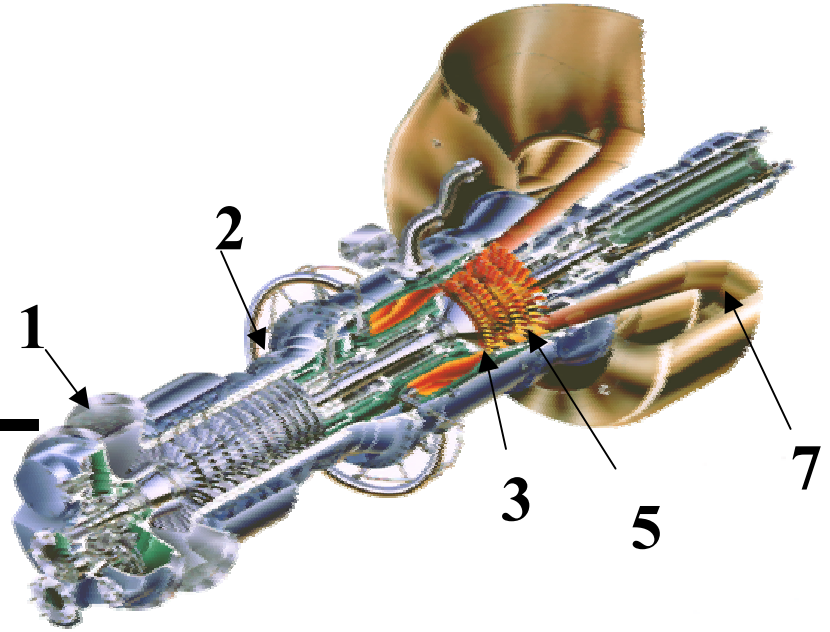
Commonalities

- Use One or Multiple Compressors
- Have Combustor
- Use One or Multiple Turbines to Drive Compressor(s)
- Aeroengines Generate Propulsion Either by a Hot Gas Jet, Driven Fan or Propeller, or Combination
- Industrial Gas Turbines Generate Mechanical Power Using Turbine Driven by Hot Gas

Brayton Cycle (Simple Cycle Gas Turbine)





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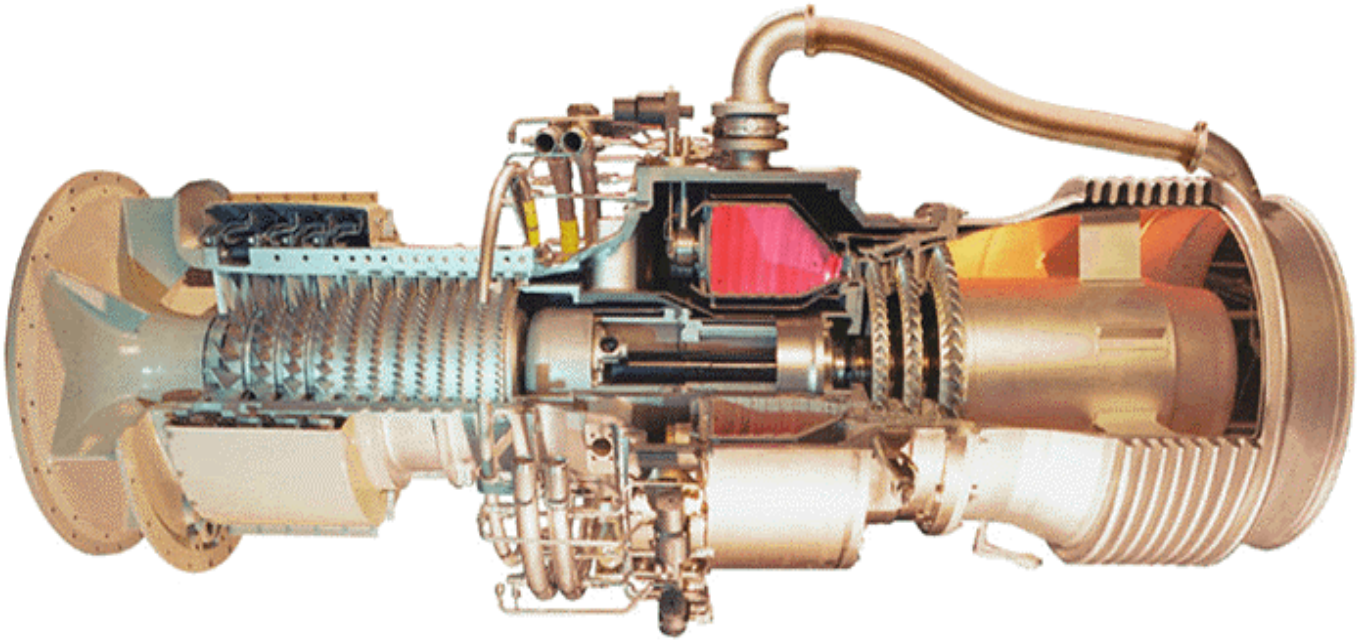
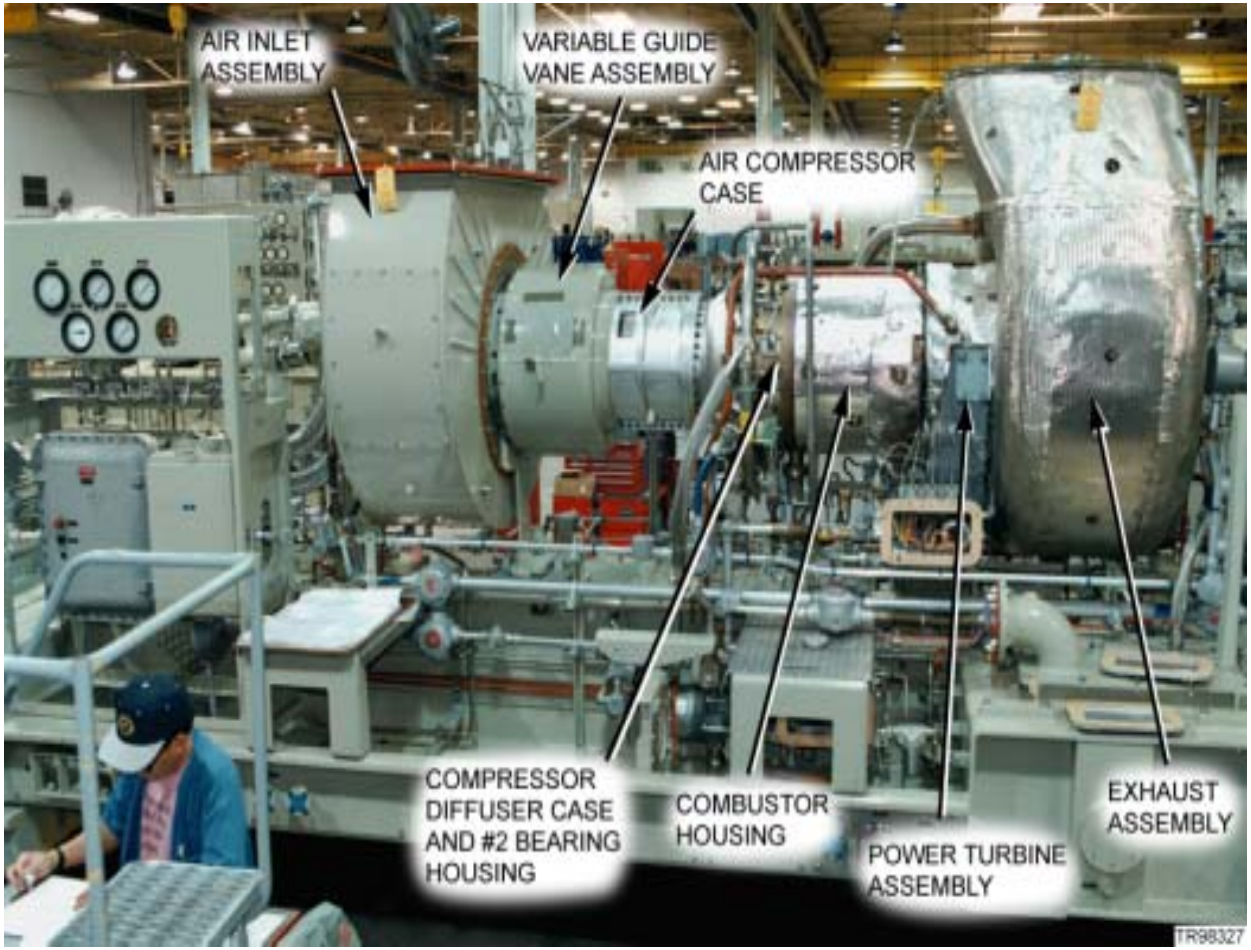
Gas Turbine Components



Engine External Components

Industrial Engine on Skid



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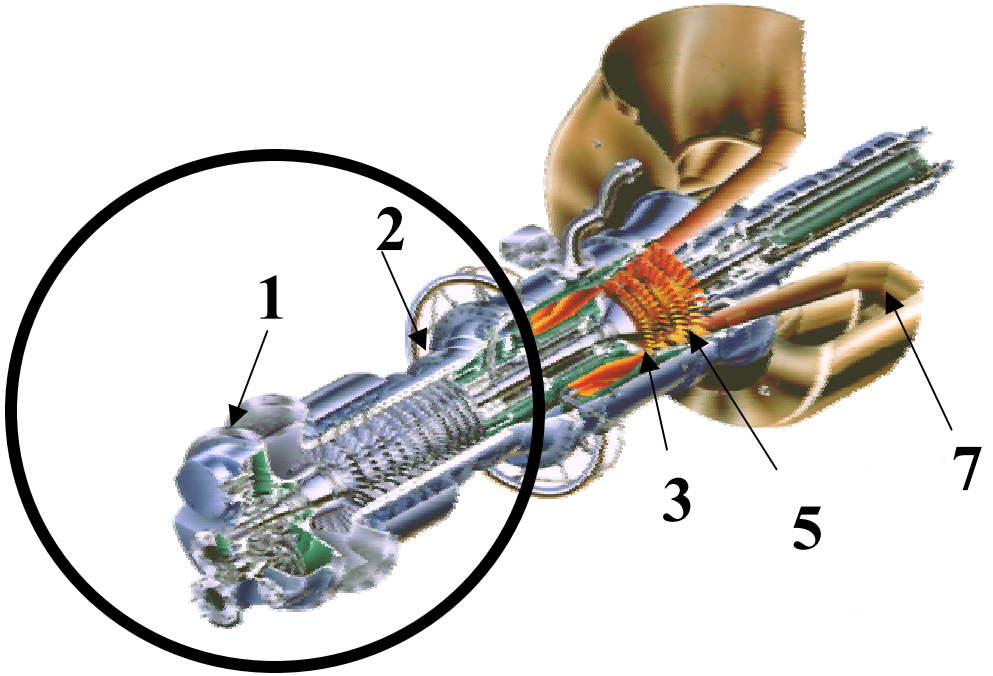
The Compressor Section

- Axial or Centrifugal Flow
- Axial Flow
  - higher efficiency
  - higher flow
  - more stages
- Centrifugal Compressors on smaller engines and some mid-size industrial engines
  - less stages
  - rugged
  - simple
- Driven by the Turbine on a Common Shaft
- Compressor Uses 2/3 of the Fuel Energy
  - That's why keeping it efficient (read CLEAN) is so important!



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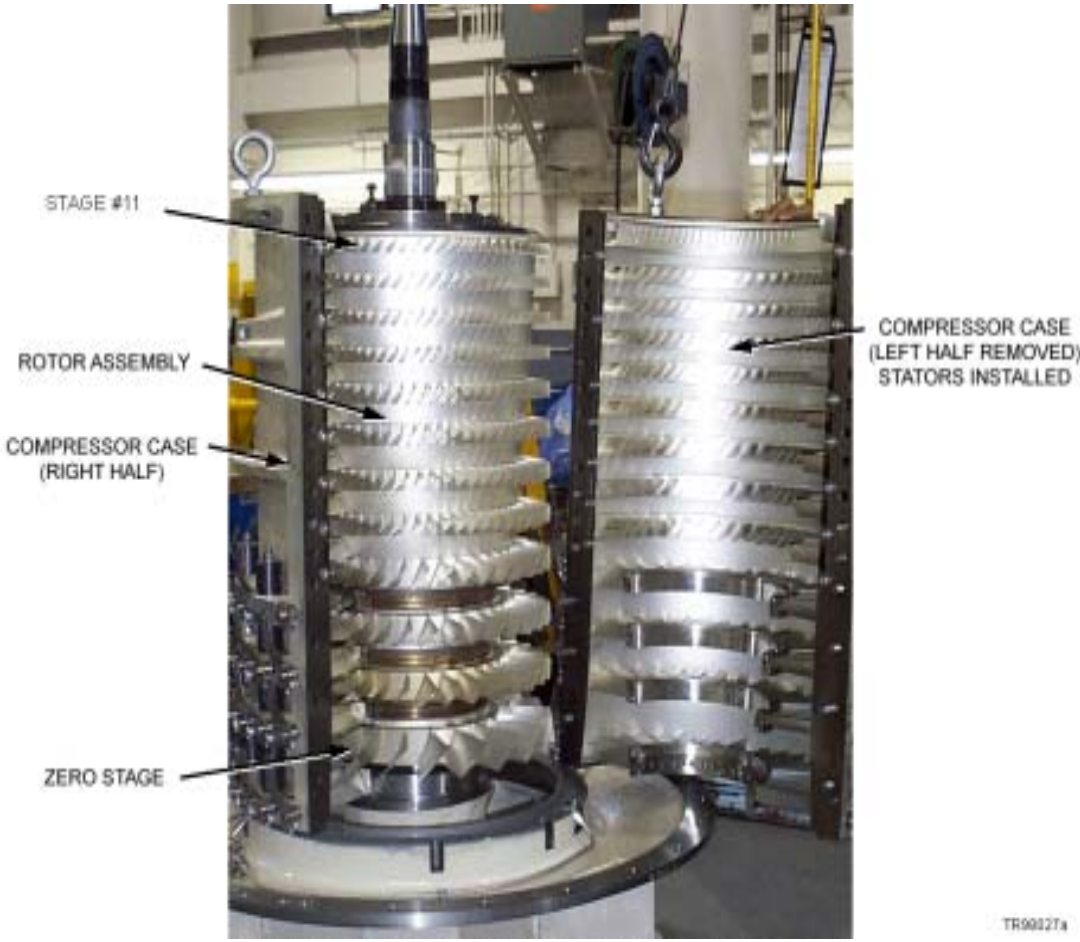
Axial Compressor

- Airflow Parallel to Rotor Axis
- Air Compressed in "Stages"
  - row of moving blades followed by row of stationary blades (stators) is one stage.
    - Moving blades impart kinetic energy
    - stators recover the kinetic energy as pressure and redirect the flow to the next stage at the optimum angle



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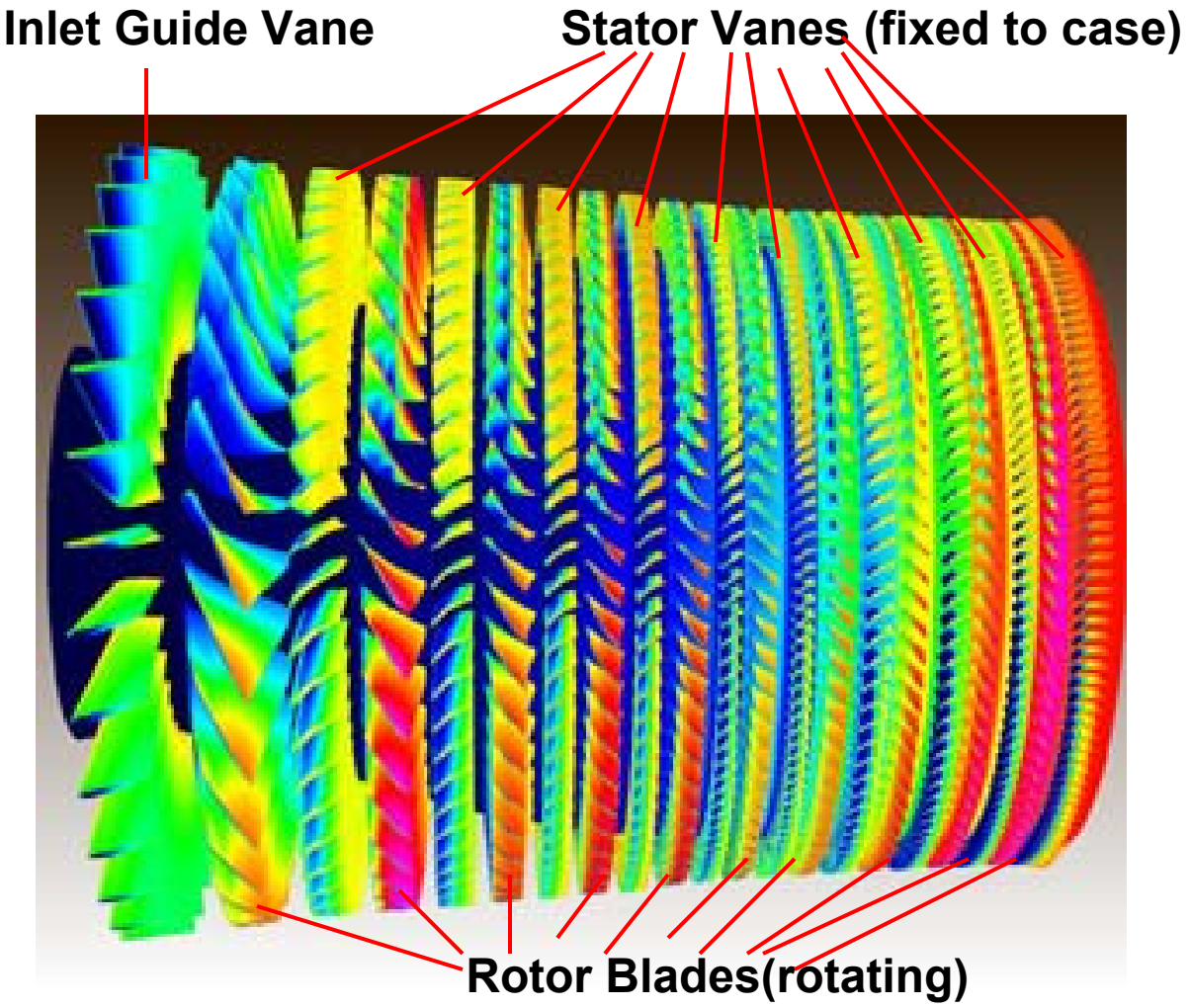
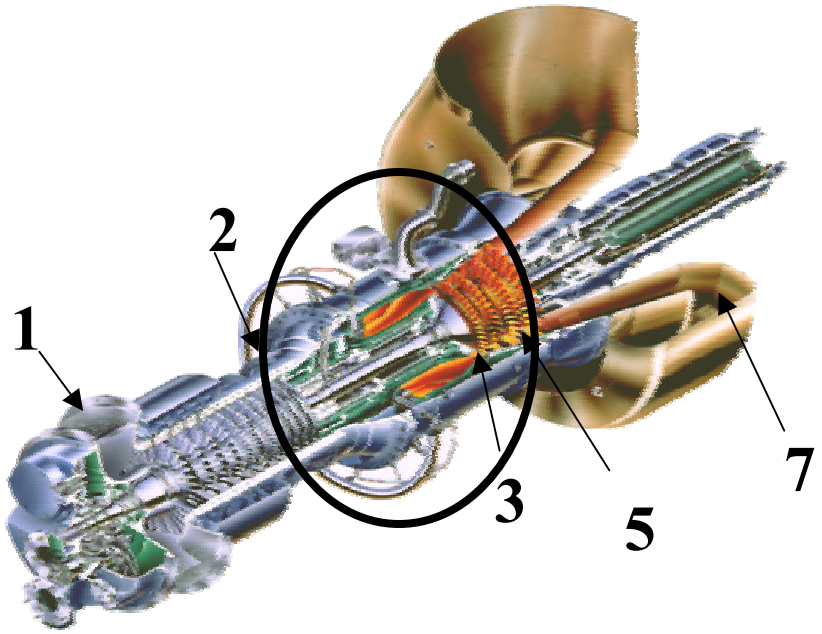
Axial Compressor

- **Modern Compressor Designs are Extremely Efficient**
  - gas turbine performance rating depends greatly on the compressor efficiency
- **High Performance Made Possible by Advanced Aerodynamics, Coatings, and Small Blade Tip Clearances**
- **Even Small Amounts of Deposits on Compressor Blades May Cause Large Performance Losses**



The Combustor

- Also Known as the “Burner”
- Must be Compact and Provide “Even Temperature Distribution of Hot Gases to the Turbine
- Three Basic Configurations:
  - annular
  - can
  - can-annular



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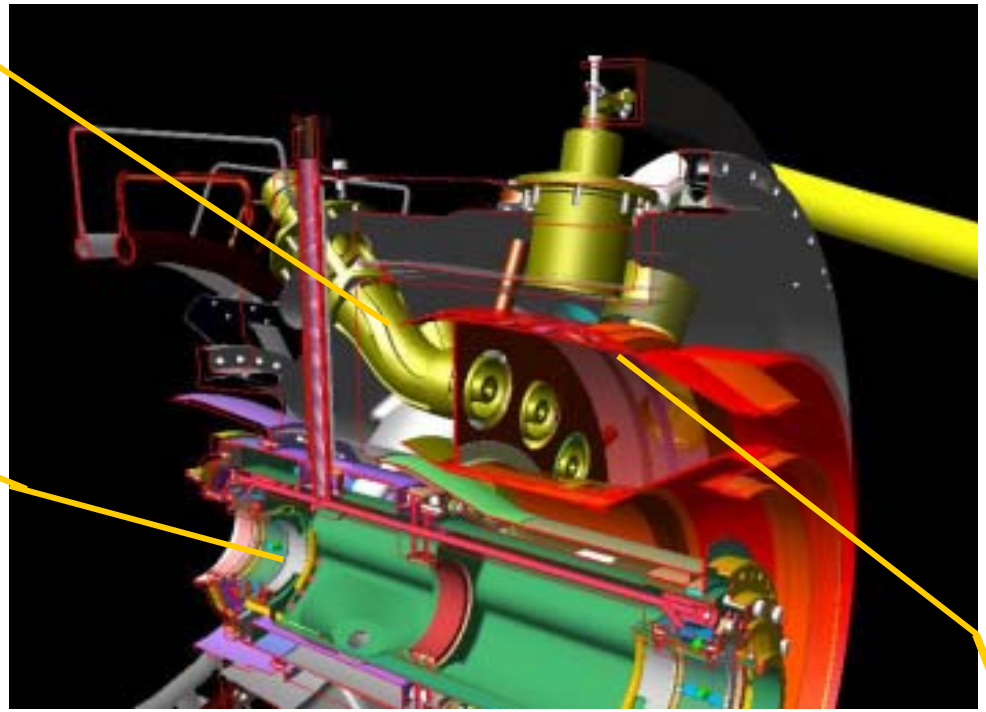
Annular Combustor



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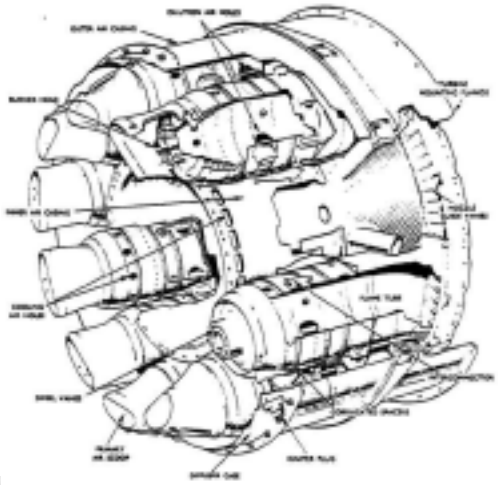
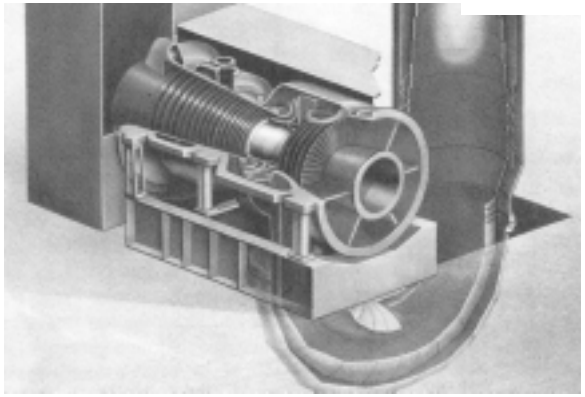
Combustor Design

- **Annular**
  - Donut shaped, single, continuous chamber that encircles the turbine

- **Can-annular**
  - multiple, single burners (“cans”) evenly spaced around the rotor shaft



- **Silo or Can**
  - One or more combustion chambers mounted external to the gas turbine body



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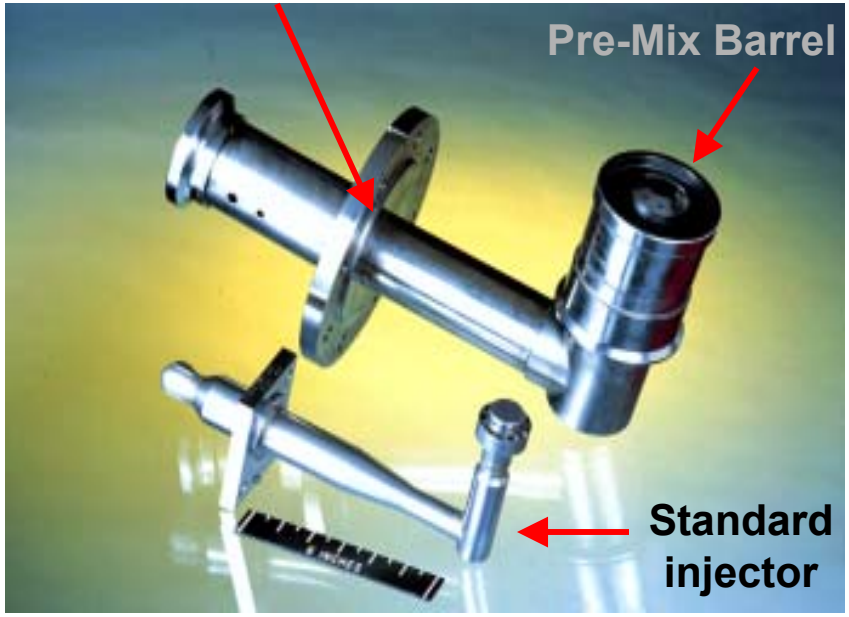
Fuel Injector

- **Used to introduce fuel into the combustion chamber.**
- **Can be for single or dual fuel**
- **Fuel can be mixed with combustion air either…**
  - in the combustor (standard combustion system)
  - pre-mixed prior to entering combustor (lean pre-mix, DLN (dry-low-Nox), DLE (dry low emissions), (SoLoNOx)

Dry-Low-NOx injector

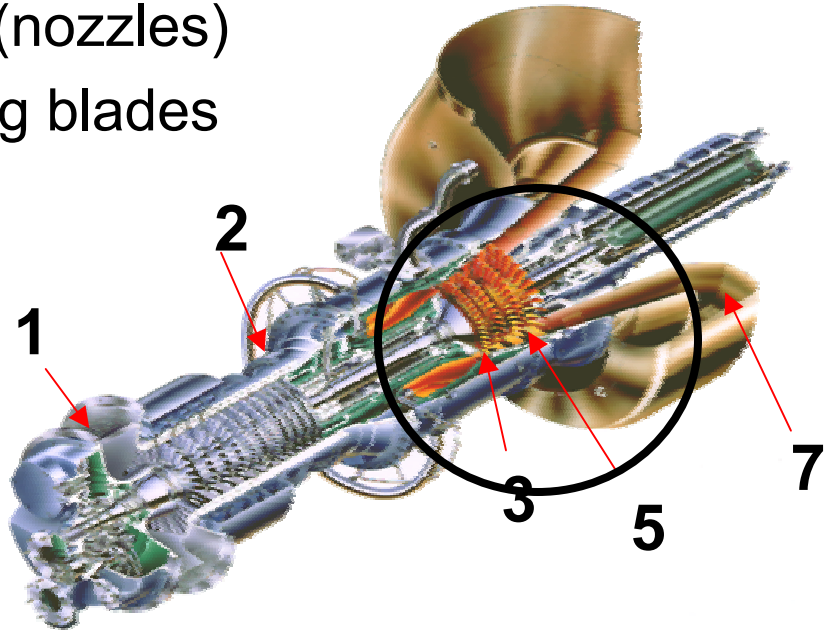


Solar Mars Injector

Standard vs SoloNOx

The Turbine

- **Two Basic Types - Radial and <u>Axial</u>**
  - Almost all industrial Gas Turbines use axial flow turbines
- **Like the Compressor, Turbine Expansion Takes Place in "Stages"**
  - a row of stationary blades (nozzles) followed by a row of moving blades = one stage.



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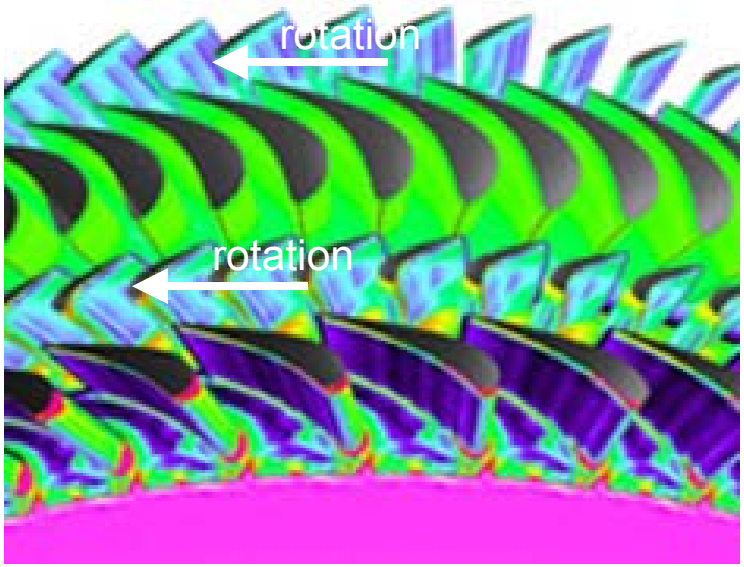
Axial Turbine

Two Stage Axial Turbine



Turbine Nozzle Segment

- First Stage Turbine Nozzle Sees the Hottest Temperatures
  - Referred to as TIT (Turbine Inlet Temperature) or TRIT (Turbine Rotor Inlet Temperature)
  - Modern engines run TRIT as high as 2200 F (some even higher)

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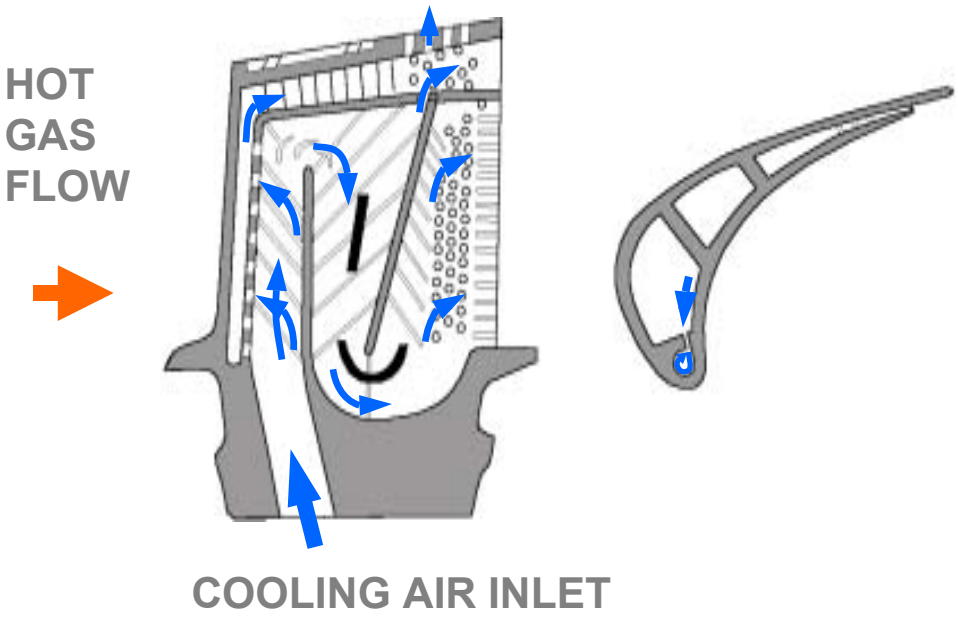
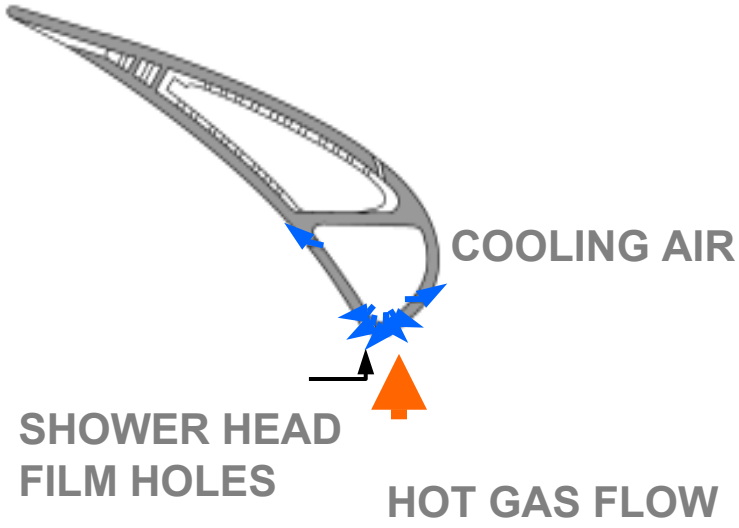
Blade Cooling Schemes





Convection Cooling

Film Cooling

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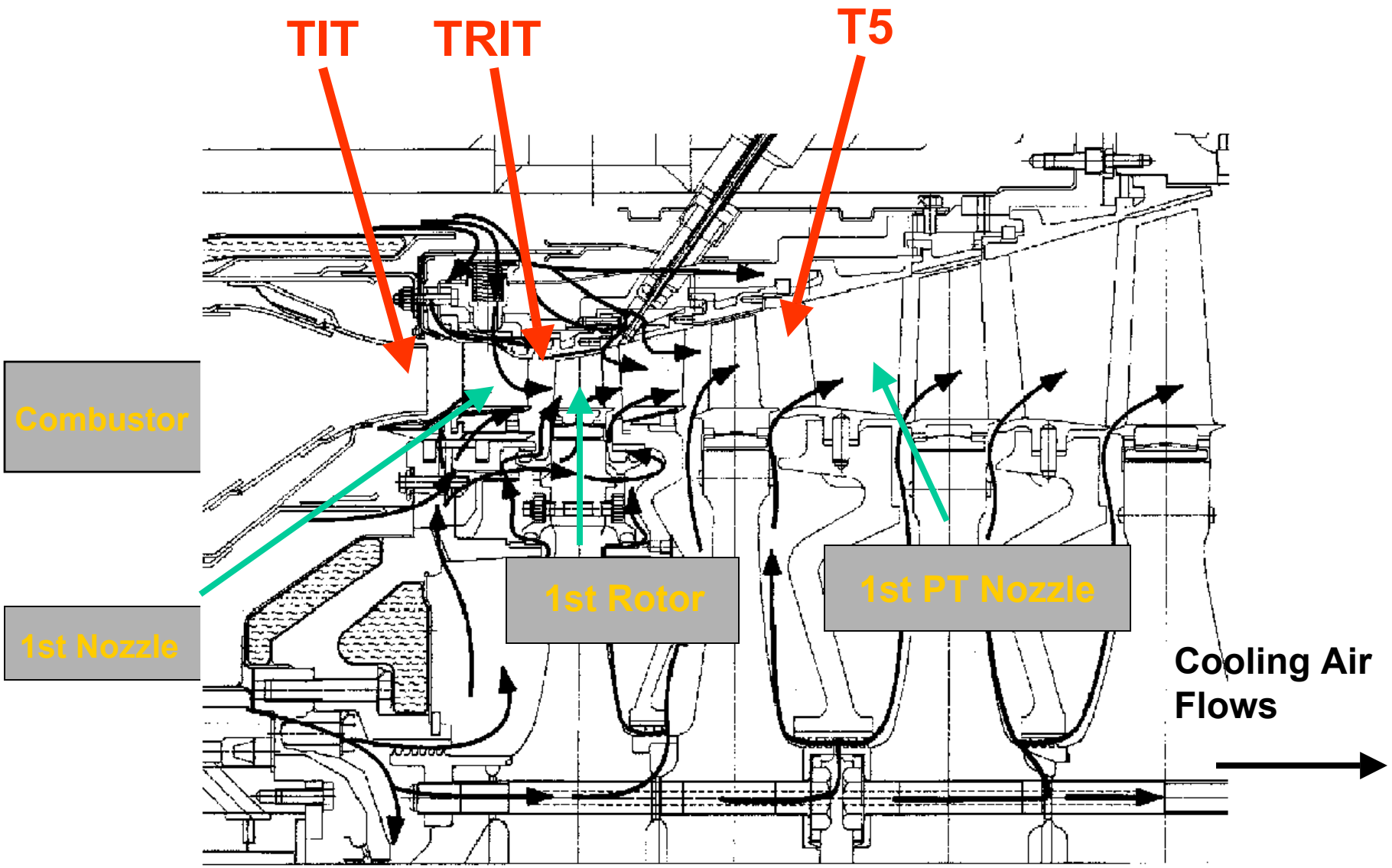
Temperature Definition



All temperatures are considered total.

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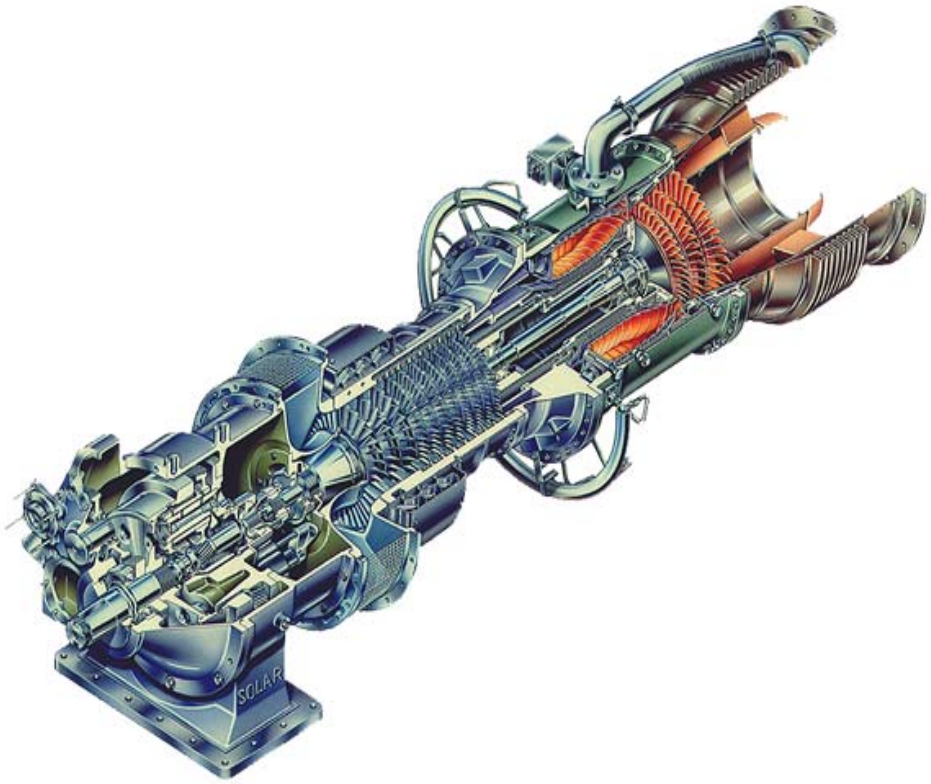
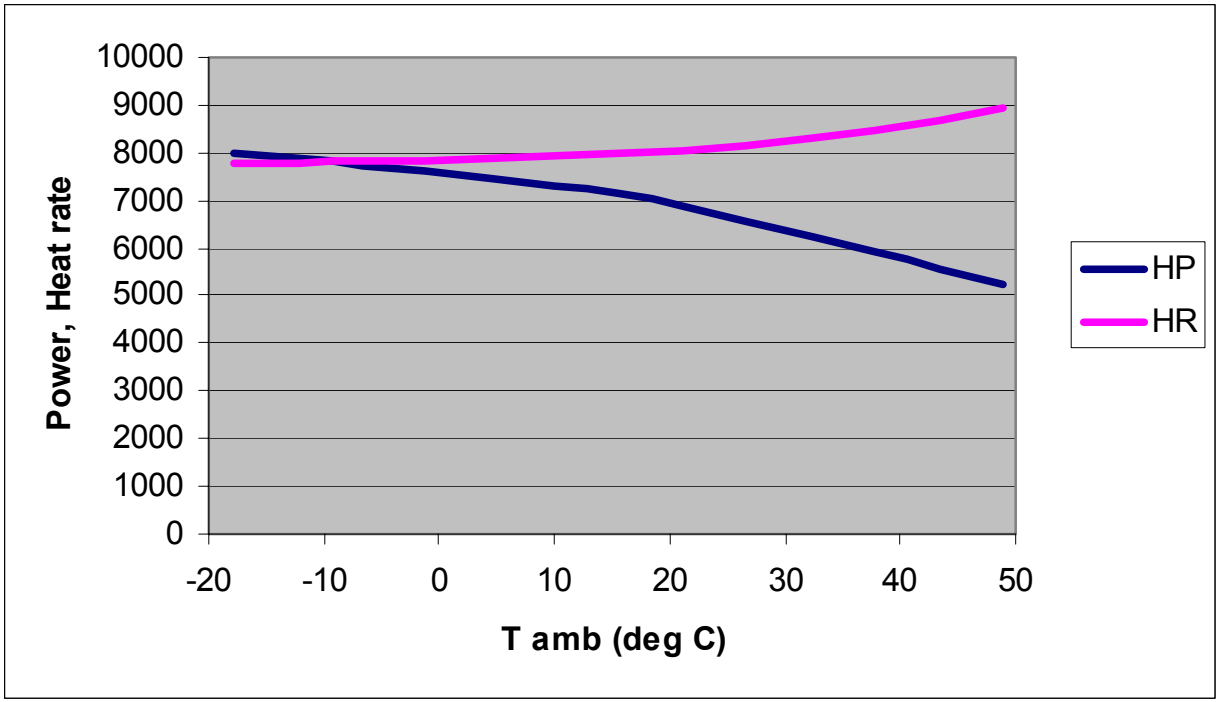
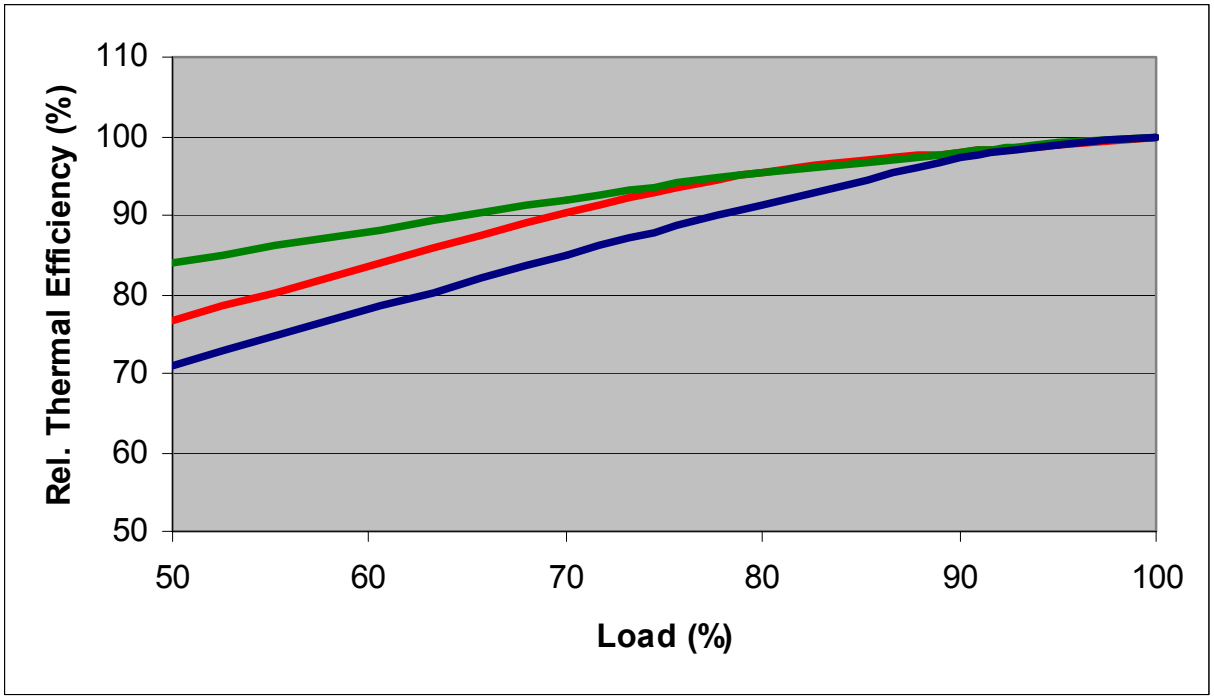
Gas Turbine Performance Characteristics



Gas Turbine
Performance vs. Ambient Temperature



Efficiency at Part Load Operation



Gas Turbine Thermal Efficiency η/η_{ref} versus Load P/P_{max}
(Typical, for 3 arbitrarily selected industrial engines)

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Gas Turbine Applications

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Industrial Applications

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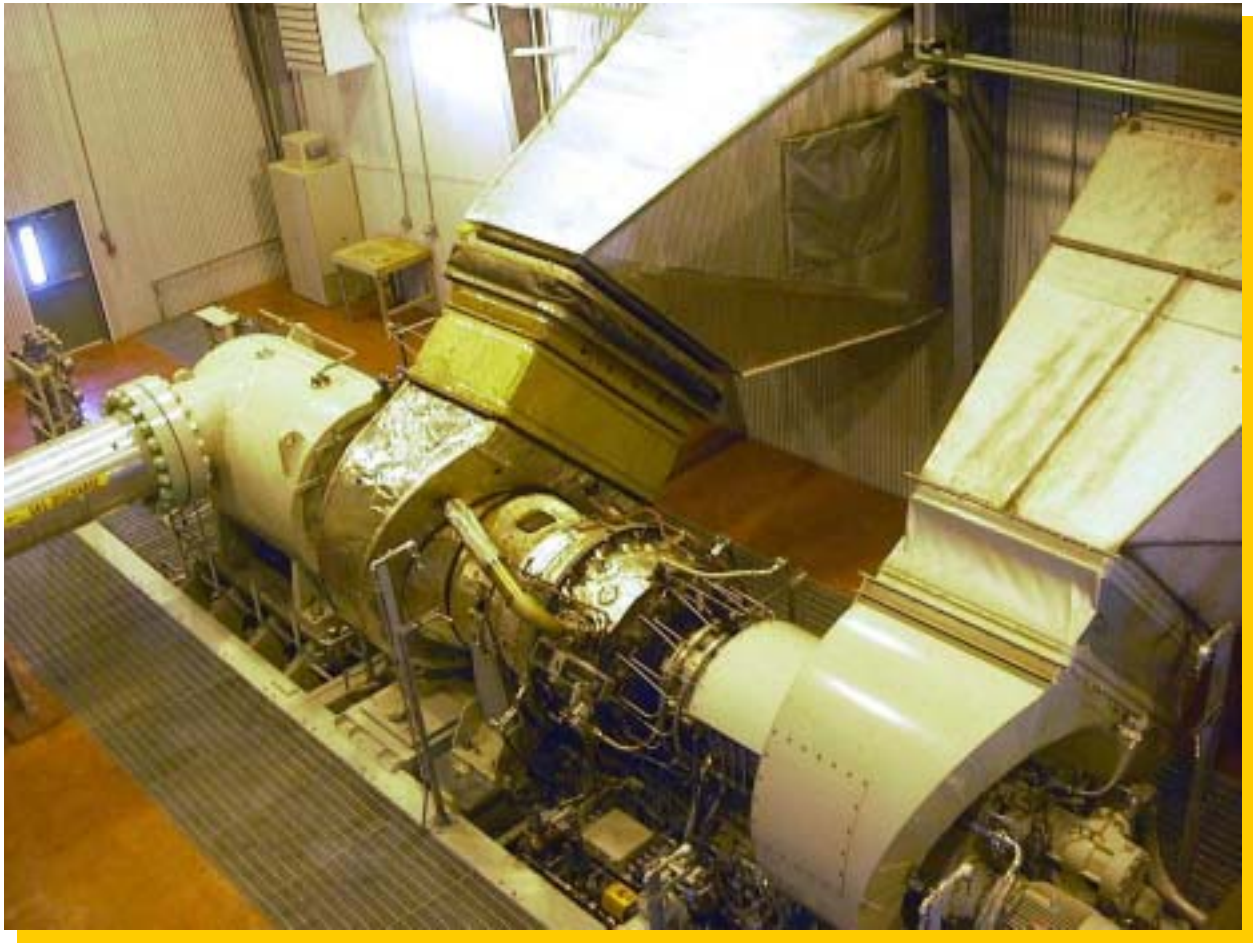
Gas Turbine Driven Compressor Set



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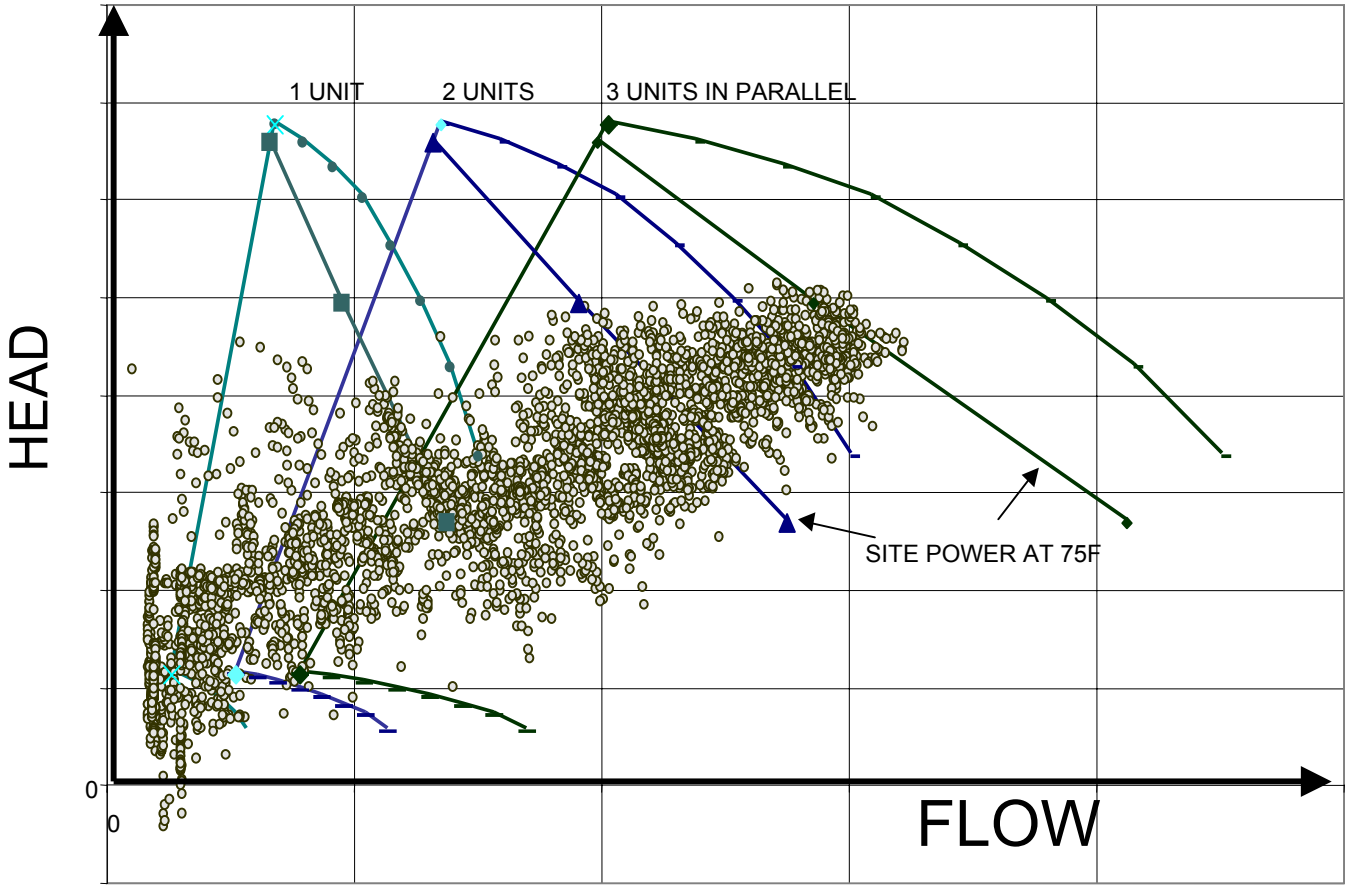
Operational Flexibility
Managing Varying Demand



Operating Points in a Compressor Station

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Gas Turbine Driven Generator

Centaur 50

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Applications

- **Base Load (Continuous Duty)**
  - Designed to operate 6,000-8,000 hrs per year (more or less continuously)
- **Peak Load**
  - Designed to operate approximately 1,000 hours per year (started during peak power demands, usually about once per day)
- **Stand-By**
  - Designed to operate less than 1,000 hours per year (started if other systems fail)
  - A “Standby Duty” unit is operated as a backup to, not in parallel with, a normal source of power.
  - Typical operation ranges from 50 to 100 hours per year with one start per week.

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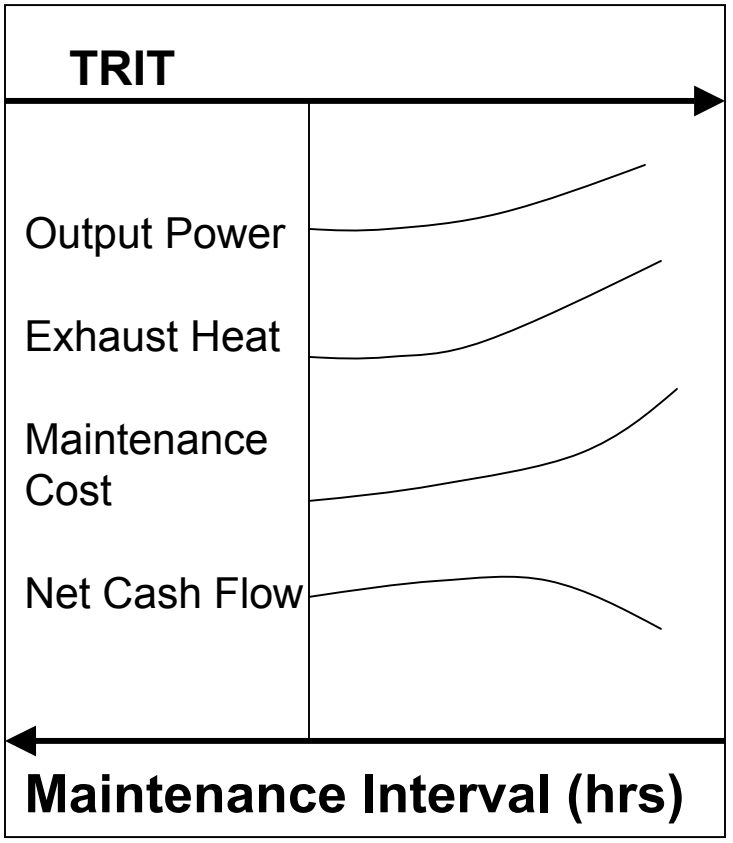
Base and Peak Load Units

- **Firing Temperature**
  - Output Power
  - Exhaust Temperature
  - Life
  - Maintenance intervals/Cost of Maintenance



Base Load, Peak Load and Stand-By Units

- **Engine Life depends on Firing Temperature (and number of starts*)**
  - Thus, a peak load unit can be fired at higher temperatures without any design changes
  - Higher Firing Temperature means more power, but shorter engine life.

*** According to some manufacturers**

Questions?